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# K RESULTS AND COMPARISONS FOR A PROPOSED STANDARD C-SPECIMEN

U.S. ARMY ARMAMENT COMMAND

**BENET WEAPONS LABORATORY**
**WATERVLIET ARSENAL**
**WATERVLIET, N.Y. 12189**

SEPTEMBER 1974

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Stress intensity factor data from a boundary value collocation method are used to determine the K calibration for a proposed standard C-shaped specimen for fracture toughness testing. The standard specimen can be readily used with hollow cylinders which have outer-to-inner diameter ratios between 1.2 and 3.0. The K calibration is described in a polynomial form similar to that used with the ASTM standard compact specimen but with an additional term dependent on diameter ratio.

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Stress intensity factor results from a standard C-specimen with shallow cracks are compared with an analysis based upon the elastic solution for a curved beam under remote bending. K results for mid-depth cracks in the standard C-specimen are compared with compact specimen results and with results from a recently proposed round specimen similar to the compact specimen. Some suggestions are given and anticipated problems are discussed related to testing with the proposed standard specimen.

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# K RESULTS AND COMPARISONS FOR A PROPOSED STANDARD C-SPECIMEN


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## ACKNOWLEDGEMENT

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## INTRODUCTION

Previous work described various aspects of the C-shaped fracture toughness specimen, including the initial development of the specimen,[1] a collocation method for determining K,[2] a general K calibration for a wide range of geometries,[3] and some fracture toughness test results.[4]

Our purpose here is to propose a standard C-specimen geometry, to determine a K calibration for that geometry with suitable accuracy for standardized fracture toughness tests, and to compare the K calibration with available K results and analyses which correspond to the C-specimen. Our procedure is to first calculate K for various geometries using the modified collocation method.[2] Then, from the K calculations, we select a standard geometry which covers a wide range of the hollow cylinder geometries which could be tested with the C-specimen. In addition, the K calibration of the standard geometry selected should be accurately represented by a simple relation, hopefully the same type of relation that is already used in ASTM-E399[5] for bend and compact specimens.

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[1]D.P. KENDALL and M.A. HUSSAIN, "A New Fracture-Toughness Test Method for Thick-Walled Cylinder Material", Experimental Mechanics, Vol 12, April 1972, pp 184-189.

[2]M.A. HUSSAIN, W.E. LORENSEN, D.P. KENDALL and S.L. PU, "A Modified Collocation Method for C-Shaped Specimens", Watervliet Arsenal Technical Report No. R-WV-T-X-6-73, Feb 1973.

[3]J.H. UNDERWOOD, R.D. SCANLON, and D.P. KENDALL, "K Calibration for C-Shaped Specimens of Various Geometries", Fracture Mechanics, ASTM STP 560, American Society for Testing and Materials, to be published.

[4]D.P. KENDALL, J. H. UNDERWOOD, and D.C WINTERS, "Fracture Toughness and Crack Growth Measurements with C-Shaped Specimens", Watervliet Arsenal Technical Report No. R-WV-T-6-39-73, Oct 1973.

[5]Standard Method of Test for Plane-Strain Fracture Toughness of Metallic Materials, E399, 1973 Annual Book of ASTM Standards, Part 31, American Society for Testing and Materials, Philadelphia, PA, 1973.

## PROPOSED STANDARD C-SPECIMEN

Unlike the standard bend and compact specimens described in ASTM-E399, a standard C-specimen cannot be a series of geometrically similar specimens which vary only in size. The C-specimen is intended to be used with the inner and outer radii of a hollow cylinder remaining unchanged to allow both economy of specimen fabrication and maximum utilization of the available wall thickness of a hollow cylinder. If a fixed ratio of outer-to-inner radius were chosen, these advantages would be eliminated except for cylinders which match the single ratio chosen. Therefore, the ratio of outer-to-inner radius, $r_2/r_1$ often called diameter ratio, is allowed to vary. The significant arbitrary dimension which must be selected for a standardized specimen design is the offset or eccentricity of the load axis relative to the bore surface, X. In order to obtain a relatively simple K calibration and efficient utilization of material, a constant ratio of $X/W = 0.5$ is now proposed. This differs from our previous recommendation in references 4 and 9, that is a constant ratio of X to inner radius, $X/r_1 = 0.7$. Figure 1 shows the range of diameter ratio which is proposed for a standard C-specimen. For specimens with X/W of 0.5 and $1.2 \leq r_2/r_1 \leq 3.0$, we believe that the K calibration described in the next section is suitable for standardized fracture toughness tests.

Two other differences should be noted between the proposed standard C-specimen and the existing standard pin loaded specimen, the compact specimen. Since the loading is more remote in the C-specimen, more latitude can be allowed in the size of the loading hole, h, relative to W. Allowing a variation in h/W will reduce the number of test

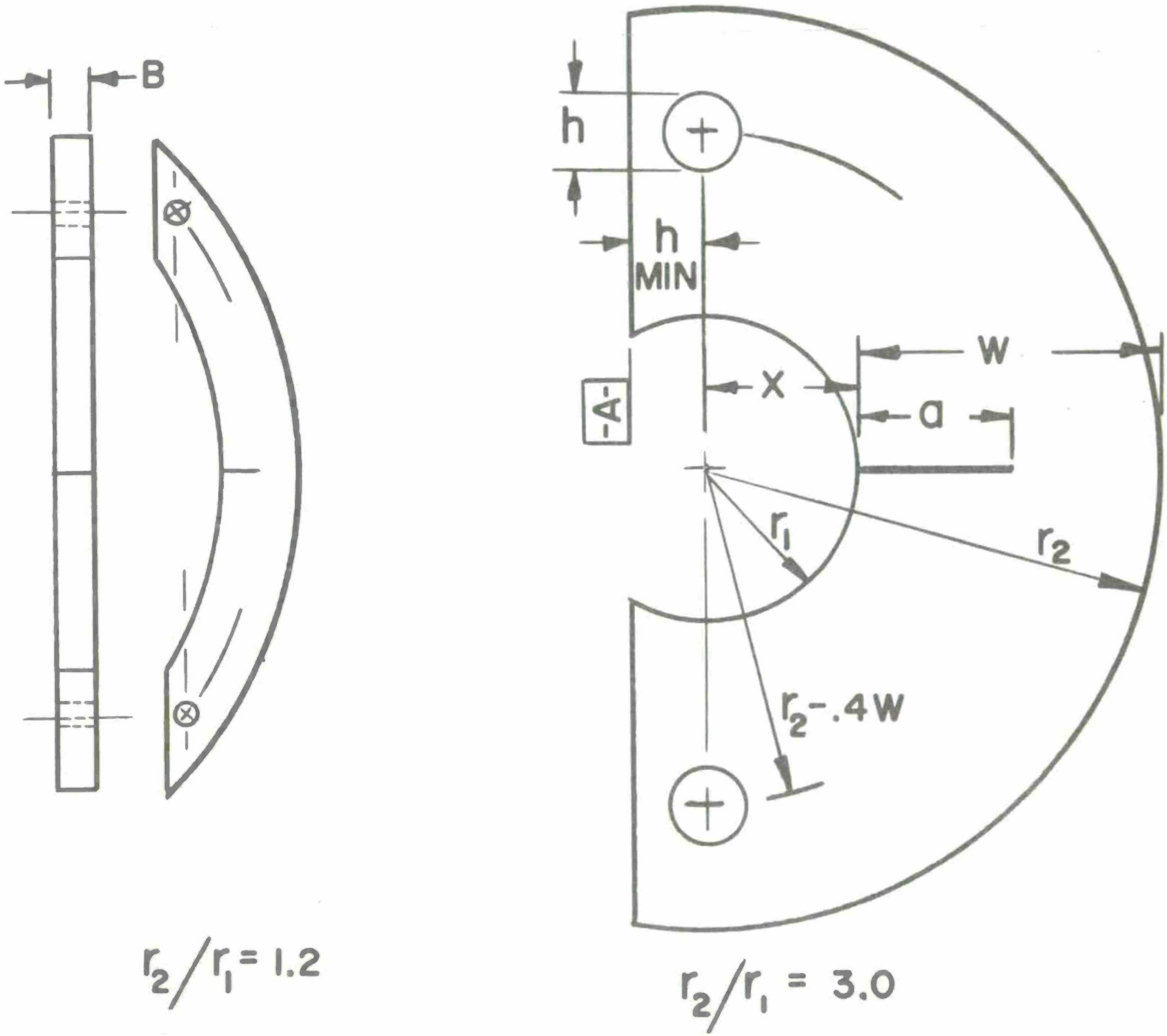


Figure 1. Specimen Geometry Showing Range of Diameter Ratio.

fixtures required to test a range of sizes of C-specimens. A second difference in the C-specimen is that displacement measurements can be made in line with the load[4] rather than on the front surface as with the compact specimen. Therefore, the corresponding surface of the C-specimen, surface A in Fig 1, is not critical and need only be a minimum distance from the loading holes.

## STANDARD SPECIMEN K RESULTS

After reviewing the existing K data[3] and several additional results including those shown in Table 1, we selected the C-specimen geometry mentioned in the previous section, that is, $X/W = 0.5$ and $1.2 \leq r_2/r_1 \leq 3.0$, as a proposed standard specimen. The data in Table 1 were calculated using the classical boundary value collocation method except that the boundary conditions are satisfied in a least squares sense. Details are in ref 2. The selection of the standard specimen and the use of the Table 1 data to establish the K calibration for the specimen were based primarily on a Wilson-Srawley type analysis of the K data. Wilson[6] described a dimensionless parameter which includes a representation of the bending moment in the uncracked ligament of a fracture specimen. Srawley and Gross[7] added the tensile

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[3] J.H. UNDERWOOD, R.D. SCANLON, and D.P. KENDALL, "K Calibration for C-Shaped Specimens of Various Geometries", Fracture Mechanics, ASTM STP 560, American Society for Testing and Materials, to be published.

[4] D.P. KENDALL, J.H. UNDERWOOD, and D.C. WINTERS, "Fracture Toughness and Crack Growth Measurements with C-Shaped Specimens", Watervliet Arsenal Technical Report No. R-WV-T-6-39-73, Oct 1973.

[6] W.K. WILSON, "Stress Intensity Factors for Deep Cracks in Bending and Compact Tension Specimens", Engineering Fracture Mechanics, Vol 2, 1970, pp 169-171.

[7] J.E. SRAWLEY, and B. GROSS, "Stress Intensity Factors for Bend and Compact Specimens", Engineering Fracture Mechanics, Vol 4, 1972, pp 587-589.

TABLE 1. C-SPECIMEN K RESULTS FROM COLLOCATION; $X/W = 0.5$, $r_2 = 4.0$

| SPECIMEN | $W$ | $r_2/r_1$ | $KB\sqrt{W}/P$ | | | | |
|---|---|---|---|---|---|---|---|
| | | | a/W=0.40 | 0.45 | 0.50 | 0.55 | 0.60 |
| F-1 | 0.70 | 1.212 | 10.93 | 12.52 | 14.58 | 17.17 | 19.59 |
| F-2 | 1.30 | 1.481 | 11.14 | 12.92 | 15.06 | 17.92 | 21.45 |
| F-3 | 2.00 | 2.000 | 11.31 | 13.07 | 15.25 | 18.09 | 21.78 |
| F-4 | 2.40 | 2.500 | 11.42 | 13.18 | 15.37 | 18.19 | 21.92 |
| F-5 | 2.65 | 2.963 | 11.49 | 13.23 | 15.43 | 18.25 | 21.98 |

TABLE 2. C-SPECIMEN COLLOCATION RESULTS WITH A DIAMETER RATIO CORRECTION

| SPECIMEN | $r_2/r_1$ | $\dfrac{KB\sqrt{W}/P}{1 - 0.0126/\ln \frac{r_2}{r_1}} = f(a/W)$ | | | | |
|---|---|---|---|---|---|---|
| | | a/W=0.40 | 0.45 | 0.50 | 0.55 | 0.60 |
| F-1 | 1.212 | 11.69 | 13.40 | 15.61 | 18.37 | 20.97 |
| F-2 | 1.481 | 11.51 | 13.35 | 15.56 | 18.52 | 22.16 |
| F-3 | 2.000 | 11.52 | 13.31 | 15.53 | 18.42 | 22.18 |
| F-4 | 2.500 | 11.58 | 13.37 | 15.58 | 18.44 | 22.23 |
| F-5 | 2.963 | 11.63 | 13.39 | 15.61 | 18.46 | 22.23 |

load per unit area in the uncracked ligament to a similar parameter. The K parameter used here was obtained in the same general manner as follows. The sum of the bending and tensile stress in the uncracked ligament of the C-specimen is simply equated to K divided by the square root of the ligament depth:

$$\frac{P(X+a + [W-a]/2)}{B[W-a]^2/6} + \frac{P}{B[W-a]} = \frac{K}{[W-a]^{1/2}} \qquad \text{(Eq 1)}$$

This results in the K parameter, denoted Y for convenience:

$$Y = \frac{KB[W-a]^{3/2}}{P(3X+2W+a)}$$

The K data from Table 1 are plotted as the above parameter in Fig 2. The data in this form are obviously quite smooth and deviate from the straight lines shown by a maximum of 0.3% over the range $0.45 \leq a/W \leq 0.55$. A systematic variation of the K data with diameter ratio is apparent both in Fig 2 and Table 1. So a K calibration for this standard C-specimen must include a function of diameter ratio for any but a very narrow range of diameter ratio.

An appreciation of the dependence of K on diameter ratio can be obtained from the relation for the circumferential stress, $\sigma_\theta$, at the inner radius of a curved beam under remote bending moment, M:[8]

$$\frac{(\sigma_\theta)_{r=r_1}}{4\,M/B} = \frac{2r_2^{\,2}(\ln\frac{r_2}{r_1}) + r_1^{\,2} - r_2^{\,2}}{(r_2^{\,2}-r_1^{\,2})^2 - 4\,r_1^{\,2}r_2^{\,2}(\ln\frac{r_2}{r_1})^2} \qquad \text{(Eq 2)}$$

[8] S. TIMOSHENKO and J.N. Goodier, Theory of Elasticity, McGraw-Hill Book Company, Inc., New York, 1951, pp 61-63.

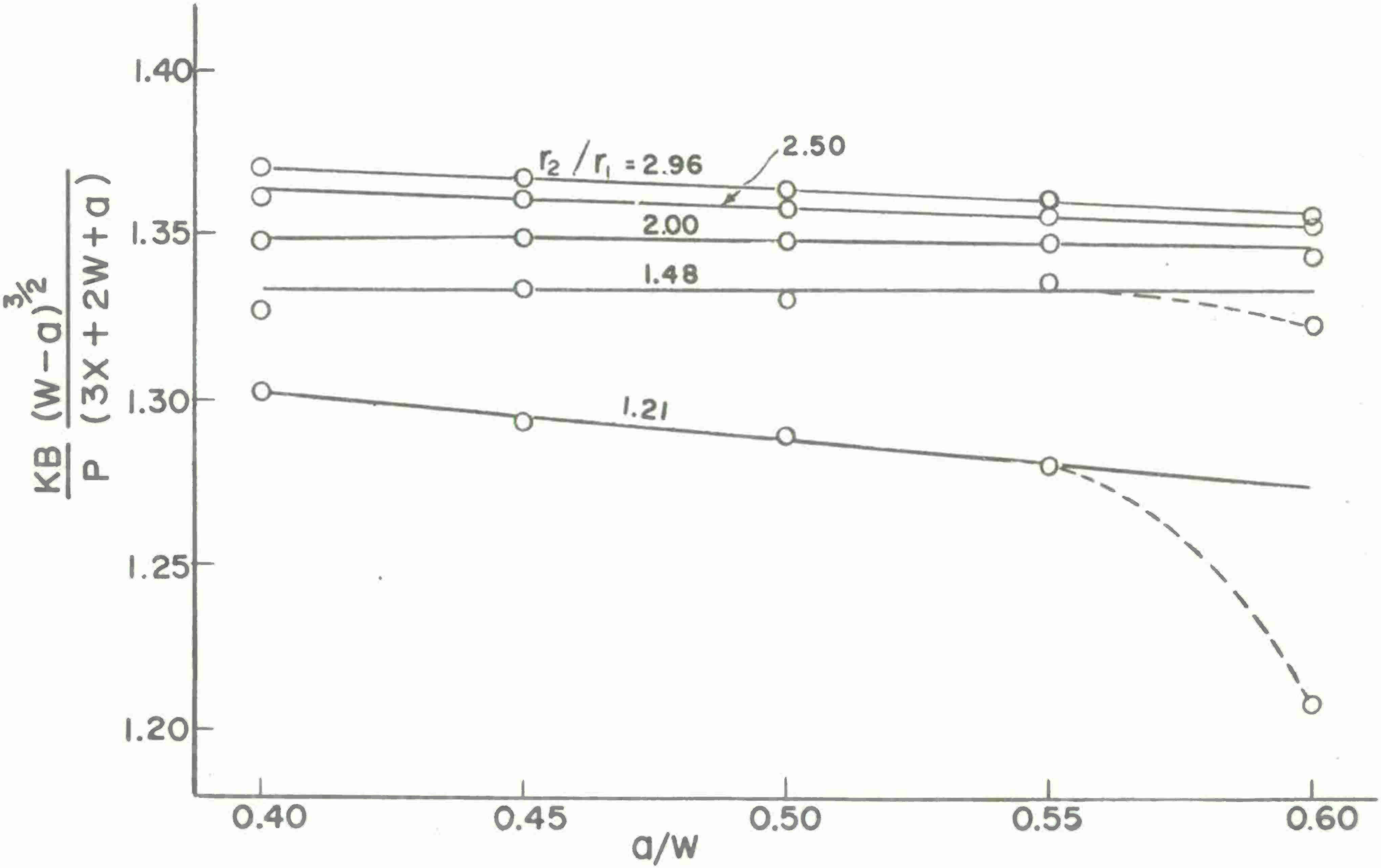


Figure 2. C-Specimen K Results as a Wilson-Srawley Parameter.

A curved beam under remote bending is quite similar to the C-specimen loading, so for short cracks Eq 2 should control the K for a C-specimen. A short-crack expression for K in C-specimens can be written as follows:

$$K=1.12\sqrt{\pi a}\left[\frac{P}{BW}+\frac{4P(X+W/2)\left(2r_2^{2}\left[\ln\frac{r_2}{r_1}\right]+r_1^{2}-r_2^{2}\right)}{BW\left(\left[r_2^{2}-r_1^{2}\right]^{2}-4r_1^{2}r_2^{2}\left[\ln\frac{r_2}{r_1}\right]^{2}\right)}\right] \qquad \text{(Eq 3)}$$

Equation 3 is the familiar $K = 1.12\,\sigma\sqrt{\pi a}$ expression for an edge crack but with the uniform tensile stress, $\sigma$, replaced by the sum of the tension and bending stress in a C-specimen. Equation 3 in dimensionless form is:

$$KB\sqrt{W}/P = 1.12\sqrt{\pi a/W}\left[1+\frac{4\left(\frac{X}{W}+\frac{1}{2}\right)\left(2\frac{r_2^{2}}{W^{2}}\left[\ln\frac{r_2}{r_1}\right]+\frac{r_1^{2}}{W^{2}}-\frac{r_2^{2}}{W^{2}}\right)}{\left(\left[\frac{r_2^{2}}{W^{2}}-\frac{r_1^{2}}{W^{2}}\right]^{2}-4\frac{r_1^{2}}{W^{2}}\frac{r_2^{2}}{W^{2}}\left[\ln\frac{r_2}{r_1}\right]^{2}\right)}\right] \qquad \text{(Eq 4)}$$

The short-crack approximation from Eq 4 and collocation data from ref 3 are plotted in Fig 3. The geometry of specimen T-3 used in the comparison is close to the standard geometry; $r_2/r_1 = 2.08$ is in the middle of the diameter ratio range, and $X/W = 0.56$ is close to standard value of 0.50. The convergence of the collocation data with the short crack relation indicates that for small $a/W$ the curved-beam bending stress controls K. In earlier work[4] a similar analysis to Eq 4 was presented based on the bending stress in a straight beam which is a reasonable approximation only for thin curved beams. We suggest that for those who need a shallow crack K calibration for C-specimens, such as for fatigue crack growth tests, Eq 4 should be nearly exact up to $a/W = 0.05$ and accurate within 5% up to about $a/W = 0.10$.

The dependence of K for deep cracks on diameter ratio is not as easy to describe analytically. With a little guidance from Eq 2, we

[4] D.P. KENDALL, J.H. UNDERWOOD, and D.C. WINTERS, "Fracture Toughness and Crack Growth Measurements with C-Shaped Specimens", Watervliet Arsenal Technical Report No. R-WV-T-6-39-73, Oct 1973.

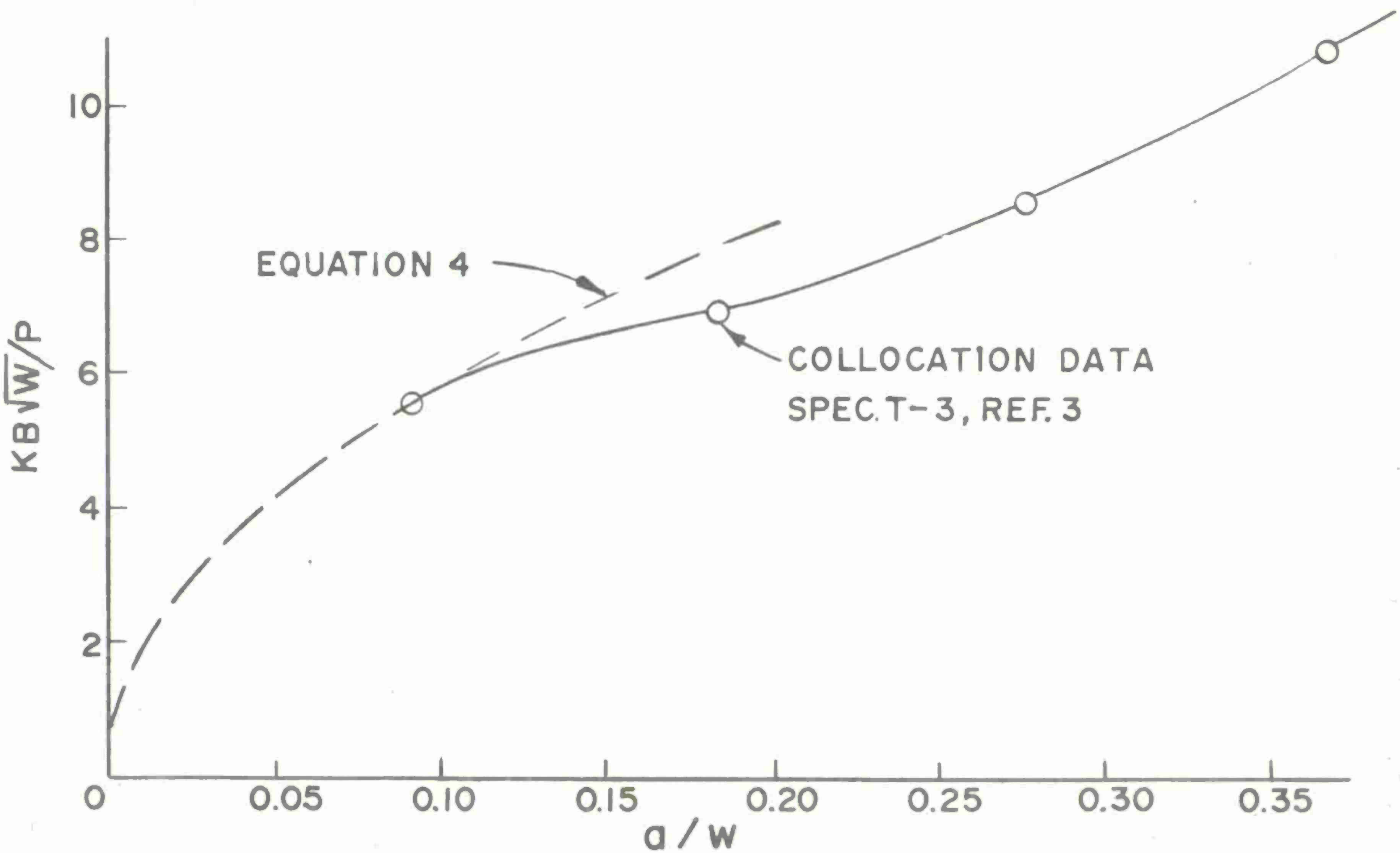


Figure 3. C-Specimen K Approximation for Short Cracks.

found an empirical function which represents the variation of K with diameter ratio for mid-depth cracks which are of primary interest for a standard specimen. Table 2 lists the collocation results from Table 1 with the empirical correction for diameter ratio applied. The $\frac{0.0126}{\ln(r_2/r_1)}$ factor brings the modified K parameter to a nearly constant value for a given value of a/W. So, the K versus a/W relation can now be determined in the usual polynomial form.

A standard least squares fit of the Table 2 data resulted in the following:

$$\frac{KB\sqrt{W}/P}{1 - .0126/\ln\frac{r_2}{r_1}} = fn(a/W) = \left[9.775(a/W)^{1/2} + 29.01(a/W)^{3/2} - 31.62(a/W)^{5/2} - 27.45(a/W)^{7/2} + 144.9(a/W)^{9/2}\right] \quad \text{(Eq 5)}$$

$$x/W = 0.5$$

$$0.45 \leq a/W \leq 0.55$$

$$1.2 \leq r_2/r_1 \leq 3.0$$

Table 3 is a tabular form of fn(a/W) from Eq 5. Equation 5 fits the collocation data within 0.5% for a/W between 0.45 and 0.55. In addition to a good fit, Eq 5 is also well behaved in that the second and third derivatives of f(a/W) are positive. The second derivative should be positive, since physically K should increase at an increasing rate for an edge-notched finite specimen.

## K COMPARISONS WITH OTHER SPECIMENS

The sketch in Fig 4 outlines a comparison of the C-specimen with the standard compact specimen and with a recently proposed round specimen[9]. The sketch is arranged so that the a and W dimensions of the round and compact specimens are identical. The C-specimen can be compared with the other two geometries if it is assumed that the inner

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9 G. FEDDERN, and E. MACHERAUCH, "A new Specimen Geometry for $K_{Ic}$-Measurements", Z. Metallkde, Vol 64, 1973, pp 882-884.

TABLE 3. C-SPECIMEN K CALIBRATION; X/W = 0.5

| a/W | f(a/W) | a/W | f(a/W) |
|---|---|---|---|
| 0.450 | 13.33 | 0.500 | 15.56 |
| 0.455 | 13.53 | 0.505 | 15.81 |
| 0.460 | 13.73 | 0.510 | 16.07 |
| 0.465 | 13.94 | 0.515 | 16.34 |
| 0.470 | 14.15 | 0.520 | 16.62 |
| 0.475 | 14.37 | 0.525 | 16.90 |
| 0.480 | 14.60 | 0.530 | 17.19 |
| 0.485 | 14.83 | 0.535 | 17.49 |
| 0.490 | 15.07 | 0.540 | 17.80 |
| 0.495 | 15.31 | 0.545 | 18.11 |
| | | 0.550 | 18.44 |

TABLE 4. COMPARISON OF C-SPECIMEN, ROUND SPECIMEN, AND COMPACT SPECIMEN K CALIBRATIONS

| "C" Specimen | | Round Specimen[10] | | Compact Specimen[7] | |
|---|---|---|---|---|---|
| a/W | $KB\sqrt{W}/P$ | $a_R/W_R$ | $KB\sqrt{\frac{2}{3}W_R}/P$ | $a_c/W_c$ | $KB\sqrt{\frac{2}{3}W_c}/P$ |
| 0.45 | 13.3 | 0.633 | 13.9 | 0.633 | 12.7 |
| 0.50 | 15.6 | 0.666 | 16.1 | 0.666 | 14.9 |
| 0.55 | 18.4 | 0.700 | 18.7 | 0.700 | 17.6 |

[7] J.E. SRAWLEY, and B. GROSS, "Stress Intensity Factors for Bend and Compact Specimens", Engineering Fracture Mechanic, Vol 4, 1972, pp 587-589.

[10] A.T. Jones, "Fracture Toughness Testing With Sections of Cylindrical Shells", Sandia Laboratories, Livermore Report SLL-73-5009, Nov 1973.

radius of the C-specimen shrinks to zero. Making this assumption, the a and W dimensions of the C-specimen can be written in terms of the corresponding dimensions for the round and compact specimens, both denoted by subscript R-C.

$$a = a_{R-C} - \frac{1}{3} W_{R-C} \qquad W = \frac{2}{3} W_{R-C} \qquad \text{(Eq 6)}$$

Table 4 shows the K calibration comparison for the three specimens. Although the comparison is made at different values of crack length and specimen width, the crack-tip position relative to the loading holes and relative to the back surface of the specimen is the same. So it is a valid comparison. The 5 per cent higher values of the C-specimen relative to the compact specimen is attributed to the missing material in the back-wall corners of the C-specimen relative to the compact specimen, as shown in Fig 4. The 3 per cent lower value of the C-specimen relative to the round specimen is attributed to the fact that Feddern and Macherauch[9] used the plane strain relation between strain energy release rate and K in the compliance K calibration for their round specimen, as indicated by their Eq 5 repeated below :

$$KBW/P\sqrt{a} = \sqrt{\frac{E\ B}{2(1-\nu^2)} \quad \frac{1}{a/W} \quad \frac{dc}{d(a/W)}}$$

The quantities E and c are elastic modulus and compliance respectively. The B/W for their compliance specimen was apparently about 0.14, as taken from their Fig 2. Our experience indicates that for a B/W of 0.5 or more, the plane strain relation between strain energy release rate and K is appropriate. For B/W values as low as 0.14, the plane

[9] G. FEDDERN, and E. MACHERAUCH, "A new Specimen Geometry for $KI_c$ - Measurements", Z. Metallkde, Vol 64, 1973, pp 882-884.

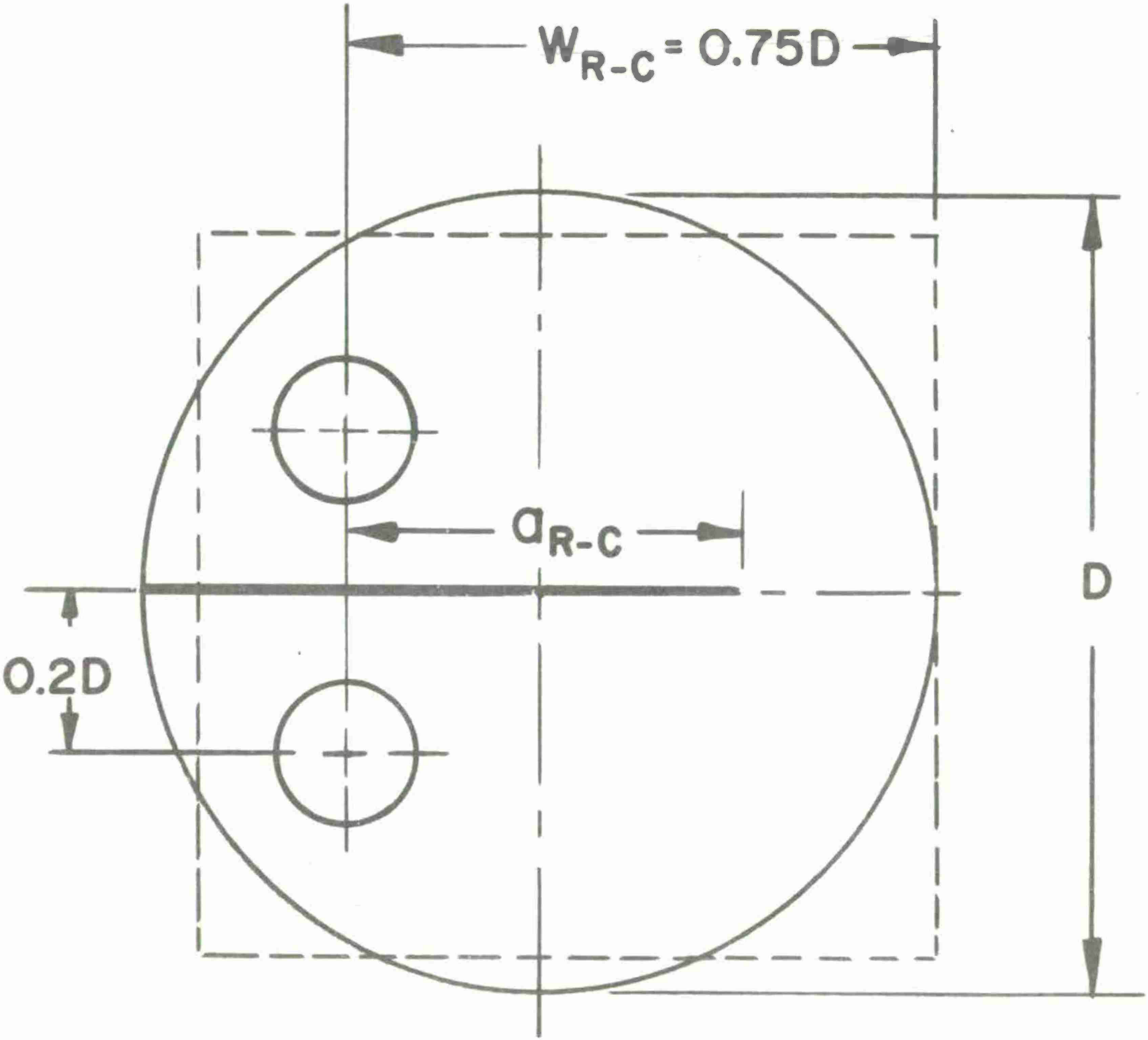


Figure 4. Round and Compact Specimens Compared With C-Specimen.

stress relation should be used even if the singular zone and plastic zone sizes are small relative to specimen thickness thus producing a plane strain condition near the crack tip. For choosing the plane strain or plane stress relation between strain energy release rate and K, the overall specimen dimensions, that is, B/W, should be used.

Another comparision can be made between the C-specimen and a cylindrical shell analysis recently described by Jones[10]. He used finite element procedures to generate K for segments from cylindrical shells. The largest diameter ratio that Jones considered, $r_2/r_1=1.25$, can be compared quite directly with the C-specimen results by using the superposition argument outlined in Fig 5. Jones' three point loading geometry with the support loads normal to the inner radius of the cylinder, case A, is equivalent to a combination of the C-specimen loading, case B, and a three point loading with the support loads parallel to the center load, case C. A comparison is possible if a good estimate is available for the loading of case C. Details of the comparison follow.

First, from plane geometry, for $r_2/r_1=1.25$ and $X/W=0.5$ the half angle of the cylinder segment is $\Theta=28.9°$ and the ratio of the span, s, to the specimen depth is $s/W=3.87$. This value of s/W is close enough to 4.0 that the ASTM E399 three-point-bending solution can be used for case C, ignoring at this point the effect of curvature.

For case A, the K parameter given by Jones for $a/W=0.5$ is:

$K_A\sqrt{r_2}\ B/P \tan\Theta = 57.$ which becomes $K_A\sqrt{W}\ B/P = 14.1$

[10] A. T. Jones, "Fracture Toughness Testing With Sections of Cylindrical Shells", Sandia Laboratories, Livermore Report SLL-73-5009, Nov 1973.

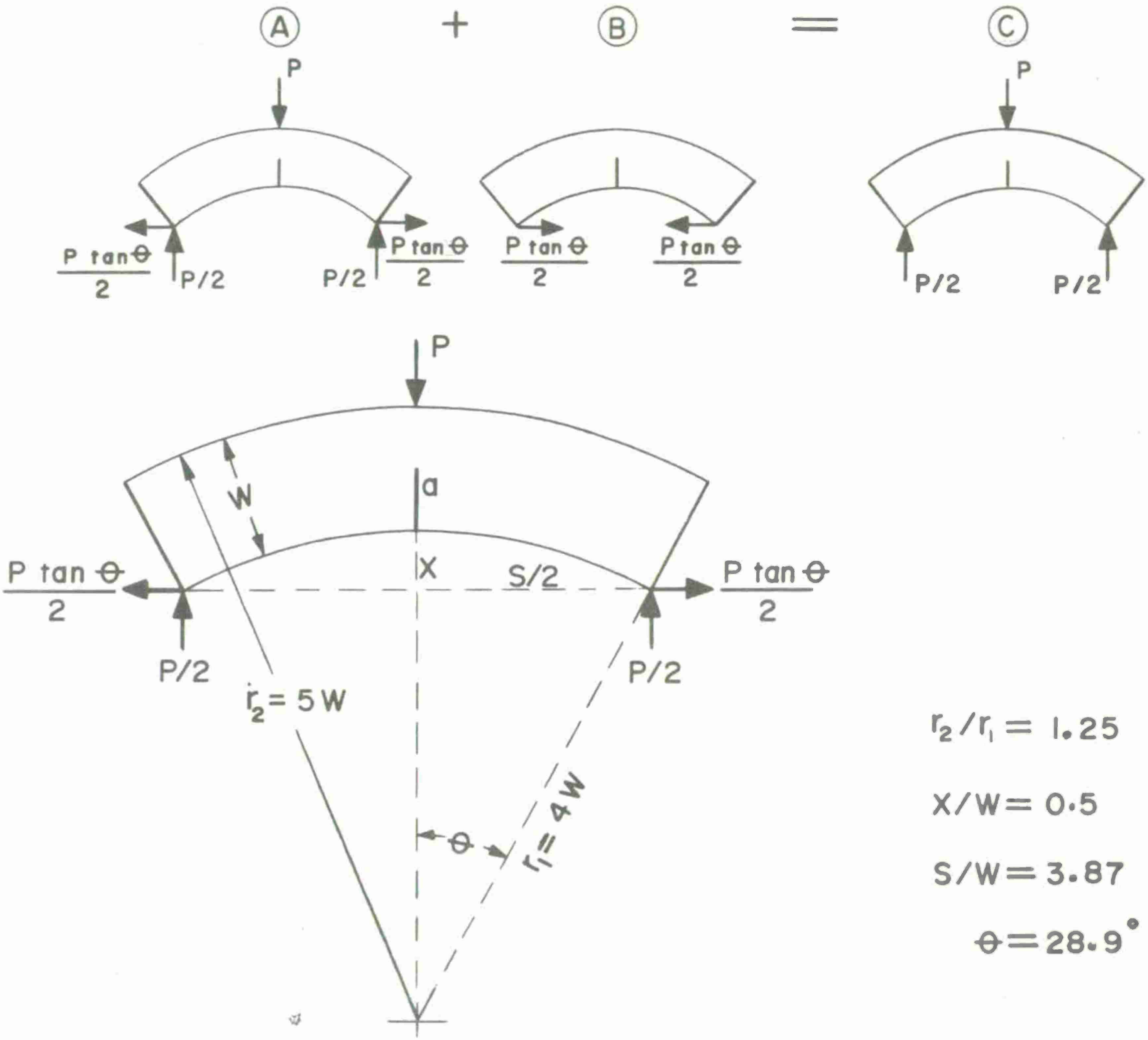


Figure 5. Comparison of C-Specimen With a Cylindrical Section in Bending.

For case B, the C-specimen K parameter from Eq 5 is: $K_B B\sqrt{W}/P^* = 14.7$, where $P^* = P(\tan\Theta)/2$. The K parameter for case B becomes $K_B B\sqrt{W}/P = 4.1$.

For case C, the K parameter from ASTM E399 is: $K_C BW^{3/2}/P_S = 2.66$, which becomes $K_C B\sqrt{W}/P = 10.3$.

The fact that $K_A B\sqrt{W}/P - K_B B\sqrt{W}/P = 10.0$ is an indication that both the C-specimen K calibration and Jones' analysis are correct. The 3 per cent higher value of $K_C B\sqrt{W}/P$ could easily be due to the use of the straight beam analysis from ASTM E399 to approximate the curved beam geometry. We would expect that for mid-depth cracks, the straight beam geometry would have a slightly higher K.

## CONCLUDING REMARKS

Based upon a) the inherent accuracy of the collocation method, b) the consistent results obtained from a Wilson-Srawley type analysis of the data, see Fig 2, and c) the comparison of the C-specimen results with the compact and round specimen results, we believe that the K calibration described herein is adequate for standardized C-specimen fracture toughness tests. We believe it represents the true K calibration within 1.0 per cent. Although the added 0.0126 ln $(r_2/r_1)$ term in the K calibration requires an added calculation, see Eq 5, the term allows the use of the K calibration over a wide range of hollow cylinder geometries.

The proposed standard C-specimen was arranged to be as similar as possible to the existing standard compact specimen. So no difficult testing problems are expected. The load efficiency of the C-specimen

is a minimum of 60 per cent higher than that of the compact specimen, that is, the K produced at a given load and for the same B and W is 60 per cent higher. The only testing problem anticipated is the interference of the material above and below the loading holes with the loading clevis. As seen in Fig 1, material would have to be removed from specimens with small diameter ratio in order to use the clevises designed for compact specimens[5]. An alternative would be to use deeper clevises.

Finally, we offer some discussion on the C-specimen hole size and its relation to the clevis loading of the specimen. We recommend a range of hole sizes from h/W = 0.25 to 0.35. With this range, one set of clevises and matching pins can be used to test a range of C-specimen sizes. Although the above range of hole sizes are generally above the standard size for the compact specimen, that is, h/W = 0.25, the large holes can be allowed due to the more remote loading of the C-specimen. The larger hole size will prevent the pin bending stress from becoming excessive. Using the standard compact specimen clevis design for C-specimens with the h/W range of 0.25 to 0.35, in no case will the ratio of clevis opening to specimen thickness exceed a value of 1.4, thus keeping the pin bending stress low.

[5]Standard Method of Test for Plane-Strain Fracture Toughness of Metallic Materials, E399, 1973 Annual Book of ASTM Standards, Part 31, American Society for Testing and Materials, Philadelphia, PA, 1973.

## LIST OF SYMBOLS

a - Crack Depth

B - Specimen Thickness

D - Round Specimen Diameter

h - Loading Hole Diameter

K - Opening Mode Stress Intensity Factor

P - Applied Load

$r_1$ - Inner Radius

$r_2$ - Outer Radius

$r_2/r_1$ - Diameter Ratio

W - Wall Thickness, $r_2 - r_1$

X - Eccentricity of Load

```
--     1   OF     1
-- 1 -  AD NUMBER: A000681
-- 2 -  FIELDS AND GROUPS: 11/6, 14/2
-- 3 -  ENTRY CLASSIFICATION:   UNCLASSIFIED
-- 5 -  CORPORATE AUTHOR: WATERVLIET ARSENAL  N Y
-- 6 -  UNCLASSIFIED TITLE:     K RESULTS AND COMPARISONS FOR A PROPOSED
--      STANDARD C-SPECIMEN.
-- 8 -  TITLE CLASSIFICATION:   UNCLASSIFIED
-- 9 -  DESCRIPTIVE NOTE: TECHNICAL REPT.,
--10 -  PERSONAL AUTHORS: UNDERWOOD,J. H. ;KENDALL,D. P. ;
--11 -  REPORT DATE:      SEP   , 1974
--12 -  PAGINATION:     25P   MEDIA COST:  $  6.00 PRICE CODE:   AA
--14 -  REPORT NUMBER:    WVT-TR-74041
--16 -  PROJECT NUMBER:   PRON-M7-3-P4539-M7-M7
--20 -  REPORT CLASSIFICATION:  UNCLASSIFIED
--23 -  DESCRIPTORS:      *CYLINDRICAL BODIES, *STANDARDS, *TEST METHODS,
--      GEOMETRIC FORMS, CALIBRATION, CRACK PROPAGATION, FRACTURE(MECHANICS)
--      , METALS
--24 -  DESCRIPTOR CLASSIFICATION:    UNCLASSIFIED
--25 -  IDENTIFIERS:      *FRACTURE TOUGHNESS, STRESS INTENSITY FACTOR
--26 -  IDENTIFIER CLASSIFICATION:    UNCLASSIFIED
--27 -  ABSTRACT:   STRESS INTENSITY FACTOR DATA FROM A BOUNDARY VALUE
--         <<P FOR NEXT PAGE>> OR <<ENTER NEXT COMMAND>>
                                                  *MSG RECEIVED*
1a ROW=24 COL= 01         <Ctrl>H For Help                         N  Poll
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